INCREASING ACCEPTANCE OF WILLOW BACCHARIS BY GOATS

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INCREASING ACCEPTANCE OF WILLOW BACCHARIS BY GOATS

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ABSTRACT

Willow baccharis (*Baccharis salicina* Torr. & Gray) is an invasive shrub in west central Texas. It quickly re-sprouts from rhizomes making it difficult to control. Herbicides that contain the active ingredient 2, 4, D will cause plant mortality but total canopy coverage is difficult because of the dense canopy cover. The plant contains sesquiterpene lactones that cause aversive post-ingestive feedback. The objectives assessed if dosing goats with activated charcoal or feeding additional protein would attenuate toxicosis. In Trial 1, the goats were dosed with activated charcoal (1 g $\cdot$ kg^{-1} BW). In Trial 2, goats were fed additional protein supplementation. In Trial 1, goats dosed with activated charcoal consumed more willow baccharis. In Trial 2, there was a trend for goats receiving additional protein to consume more willow baccharis. It appears that both activated charcoal and additional protein supplementation may improve intake of willow baccharis.

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INTRODUCTION

Willow baccharis (*Baccharis salicina* Torr. & Gray) is a native shrub in the Asteraceae family (sunflower family) (Boldt 1989). It is a smooth shrub that grows 1-3 m tall and blooms in late summer and fall. It provides little to no value to grazing livestock or wildlife apparently because the plant contains secondary compounds that result in aversive post-ingestive feedback and the formation of conditioned food aversions (Munoz et al. 2017).

Willow baccharis can be found mainly in moist soils near lakeshores, riverbeds, watersheds, disturbed soil sites, and riparian zones (Hatch & Pluhar 1993). It is invasive and will outcompete more beneficial range plants. It grows in dense stands, tightly compacted together making livestock, wildlife, or human maneuverability difficult. The dense overgrowth allows little to no sunlight underneath the canopy reducing herbaceous cover. The shrub's proximity to water coupled with its dense overgrowth makes access to water difficult.

Control of the plant is difficult. Mechanical control and prescribed burning are ineffective because the plant quickly re-sprouts from rhizomes remaining in the soil (Boldt 1989). Some herbicide mixtures that contain the active ingredient 2, 4, D will cause plant mortality, but effective canopy coverage is often difficult because of the dense canopy cover.

Willow baccharis contains sesquiterpene lactones that are toxic to livestock and wildlife (Cheeke 1997). Previous research showed that goats avoid the plant because of aversive post-ingestive feedback (Munoz et al. 2017). Others have shown that dosing with some compounds (e.g., activated charcoal) or feeding additional protein may attenuate

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aversive post-ingestive feedback from some poisonous plants. Protein supplementation high in amino acids that escape rumen degradation improves intake of some chemically defended plants like redberry juniper (*Juniperus pinchotii* Sudw.) (George et al. 2010; Anderson et al. 2013). Activated charcoal attenuates toxicosis from the toxic forb bitterweed (*Hymenoxys odorata* DC) that contains sesquiterpene lactones (Poage et al. 2000; Bisson et al. 2001). Preliminary studies have shown that dosing with activated charcoal improves intake of willow baccharis. While protein supplementation improves intake of some plants, it is not known if protein supplementation will improve intake of willow baccharis. This study assessed the impact of (1) dosing with activated charcoal and (2) additional protein supplementation on intake of willow baccharis.

OBJECTIVES

The objectives of this study were to determine: (1) if dosing with activated charcoal improves intake of willow baccharis, and (2) if feeding additional protein improves intake of the plant.

LITERATURE REVIEW

All animals form aversions to feedstuffs and plants that cause aversive post-ingestive feedback (Provenza 1995). Once gastrointestinal malaise is experienced, animals associate the taste of the food with nausea and avoid the food thereafter (Garcia and Koelling 1966). Ruminant animals may consume small amounts of toxic plants to meet nutritional needs but usually avoid the plant unless alternative nutritious forage is limited. If alternative forage is limited, animals over-ingest may suffer from plant-induced toxicosis (Provenza 1995).

Dosing with activated charcoal can alleviate the likelihood of some plant-induced toxicosis (Buck & Bratich 1986). The compound binds many toxins in the digestive tract, allowing for excretion (Hayden & Comstock 1975). Most toxins possess a negative charge and will readily bind to the positively charged activated charcoal. Unfortunately, activated charcoal is ineffective in reducing toxicity from some compounds like those found redberry juniper (Bisson et al. 2001)

Poage et al. (2000) illustrated that activated charcoal would attenuate bitterweed toxicosis in lambs. Lambs not dosed with activated charcoal avoid bitterweed (Fuchs et al. 2017), while those dosed with activated charcoal readily consume the plant and avoid toxicosis. Others have reported that activated charcoal improved intake of chemically defended shrubs as well (Rogosic et al. 2006).

Exposure to some poisonous plants at weaning improves intake of the plant later in life (Munoz et al. 2017; Borroum et al. 2018). Both sheep and goats readily accept redberry juniper after exposure to the plant at weaning. Likewise, Distel and Provenza (1991) showed that exposure to blackbrush (*Coleogyne ramosissima* Torr.) at weaning improved intake of the plants. Blackbrush contains condensed tannins that cause aversive post-ingestive feedback. Goats exposed to the plant at weaning consumed 95% more than naïve goats and excreted more uronic acid apparently because of an enhanced ability to detoxify tannins found in the plant. Preconditioning goats to consume salt cedar (*Tamarix ramosissima* Ledeb.) and willow baccharis (*Baccharis salicina* Torr. & Gray.) also increases acceptance of salt cedar, but not willow baccharis (Munoz et al. 2017). Salt cedar apparently does not cause aversive post-ingestive feedback and is nutritious (Knight et al. 2012).

Unfortunately, exposure to toxic foods early in life only improves intake if exposure results in enhanced ability to detoxify and excrete toxic compounds. Previous research with willow baccharis at weaning did not improve intake of the plant (Munoz et al. 2017). In addition, feeding proteins that escape ruminal degradation improves intake of some toxic plants like redberry juniper. Protein sources that escape rumen metabolism and are high in glucogenic amino acids increase the likelihood of detoxification because the amino acids act as the substrate for conjugation (George et al. 2010; Anderson et al. 2013).

This project used the same approach using escape proteins to increase intake as well as activated charcoal to bind to the toxins in willow baccharis. This should allow absorption of the nutritive values in the plant but will allow the toxins to pass without absorption through the digestive system.

METHODS

This research project consisted of two trials and took place over a span of 21 days in 2019 and 2020. Both trials were conducted at the Angelo State University Management Instruction and Research (MIR) Center (31.5 Long, -100.5 Lat.). Twenty recently-weaned Boer-Spanish cross goats (10 male & 10 female) that weighed an average of 25 kg were placed into individual research pens (1 m by 1.5 m) in each trial. Goats used in Trial 1 were different goats than those used in Trial 2. The first 7 days was an acclimation period to allow adaptation to individual pens. The goats received fresh water and a trace mineral mix *ad libitum*. In addition, the goats received alfalfa pellets (3% BW) daily to meet maintenance requirements (NRC 2007). Alfalfa was fed each morning at 0830 hours. Any refusals were collected 24 hours later and weighed to estimate intake. All procedures were approved by the Angelo State University Animal Care and Use Committee prior to the initiation of the study.

Willow baccharis leaves and green tender stems were hand-picked from randomly selected trees weekly at the MIR Center for both trials. Plant material was hand-mixed, composited, and stored at 4° C to maintain freshness.

Trial 1

Goats in each treatment were offered 50 g of willow baccharis daily at 0800 hours. In addition, 10 goats were dosed with activated charcoal (1 g $\cdot$ kg^{-1} BW) immediately before feeding willow baccharis. Activated charcoal was administered orally by dosing animals with the compound Universal Animal Antidote, which contains activated charcoal in a paste suspension. Immediately after dosing, willow baccharis was offered for 30 minutes daily for 15 days. Initially 50 g of willow baccharis was fed daily. If a goat consumed all of the willow baccharis offered for two consecutive days, the amount offered was increased by 25 g until refusals were noted. Refusals collected on 0830 each day to estimate intake. Thereafter, alfalfa pellets were fed (3% BW) for the remainder of the day to meet maintenance requirements.

Trial 2

Ten goats were fed a protein supplement (Table 1) 30 minutes before feeding willow baccharis. The amount of the supplement fed to goats was based on providing 1.9 g · kg^{-1} BW of additional protein to surpass daily requirements for growth (NRC 2007). Based on average weight (25 kg), goats received 130 g · head · day^{-1} of the 37% CP supplement.

The 10 remaining goats were only fed willow baccharis (control). Willow baccharis was offered for 30 minutes daily for 14 days. Refusals were collected at 0830 to estimate intake. As goats consumed all 50 g of willow baccharis fed, intake was increased daily by 25 g until refusals were noted. All animals were weighed initially and after completion of the study. Initial weights were compared to ending weights to assess weight change among treatments.

Intake data was converted to g · kg^{-1} BW to account for variations in body weight among individuals. In both trials, differences between treatments (activated charcoal vs control or protein supplementation vs. control) were compared as a completely randomized design using repeated measures analysis of variance. Animals nested within treatments served as replications and day of collection as the repeated measure. Means were separated using Tukey's Protected LSD when $P \leq 0.05$. Data was analyzed using the statistical package JMP (SAS 2007).

Table 1. Ingredients and nutrient content of the protein supplementation used in this study. Water and trace mineral mix were provided *ad libitum*.

Ingredients	%
Cottonseed Meal	77.5
Distiller's Dried Grains	16.2
Cane Molasses	3.4
Rice Bran	2.5
Trace Minerals	0.02
Vitamins A, D, and E	0.3
Nutrient Content	
Total Digestible Nutrients	72.3
Protein	36.0
Digestible Energy (Mcal · kg-1)	5.54
Amount Fed ($g \cdot hd^{-1} \cdot day^{-1}$)	130.0

RESULTS

Trial 1

Intake (g · kg^{-1} BW) of willow baccharis differed by treatment and by day. The treatment by day interaction was similar ($P = 0.83$). Goats dosed with activated charcoal consumed more willow baccharis than goats that were not dosed (Fig. 1). Intake of willow baccharis increased for all goats over the 15 days of feeding (Fig. 2). Goats dosed with activated charcoal tended to consume more willow baccharis each day of feeding but intake varied daily. Goats consumed all of the alfalfa pellets fed each day (data not shown).

Trial 2

Goats fed the protein supplement prior to offering willow baccharis consumed all of the supplement each day (data not shown). There was a trend for goats supplemented with protein to consume more willow baccharis, but the treatment effect did not differ (Fig. 3). Similar to Trial 1, willow baccharis intake increased for all goats over the 14 days of feeding with some daily fluctuations (Fig. 4). On most days, goats receiving additional protein tended to consume more willow baccharis. In addition, alfalfa intake increased over the 14 days of feeding for all goats as well (Fig. 5).

All goats lost weight but weight differences were similar between treatments. Goats supplemented with additional protein lost 0.05 kg ± 0.84 kg while no supplemented lost 2.00 kg ± 0.84 kg from the beginning to the end of the trial.

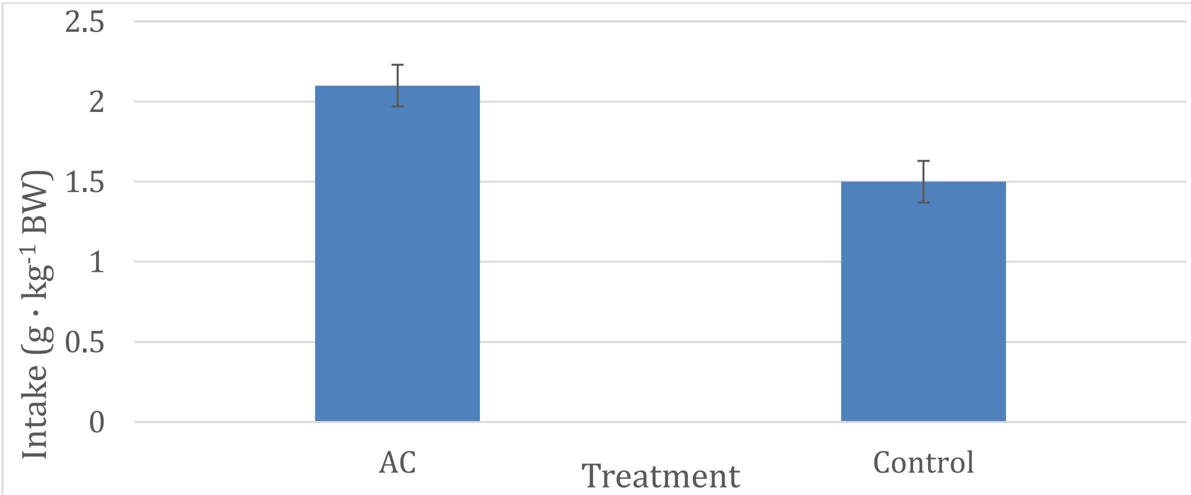

Figure 1. Average intake (g · kg^{-1} BW) of willow baccharis by goats dosed with activated charcoal vs the control (not dosed) in Trial 1. Goats in both treatments were offered willow baccharis for 15 days.

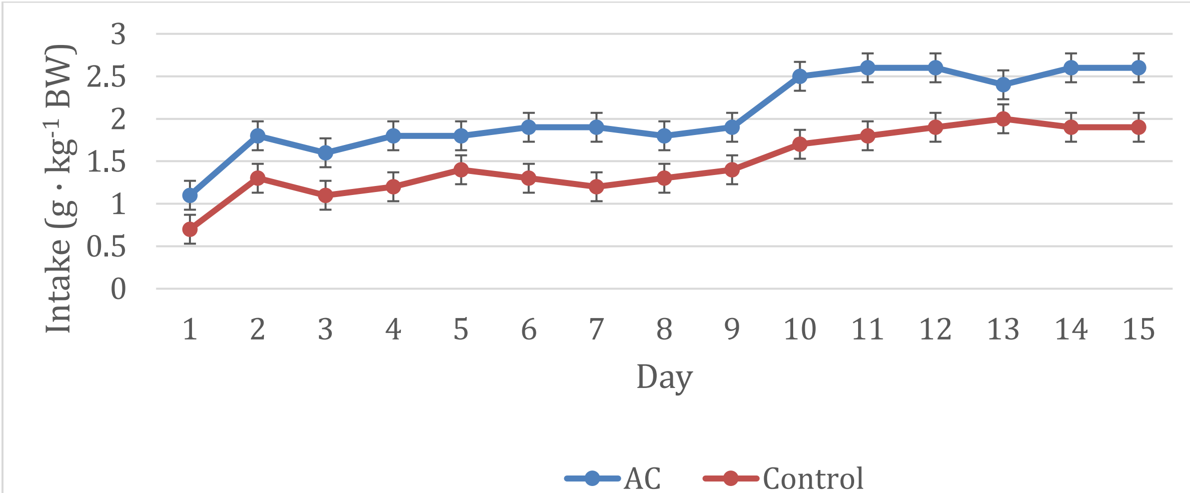

Figure 2. Average daily intake (g · kg^{-1} BW) of willow baccharis by goats dosed with activated charcoal vs the control (not dosed) in Trial 1.

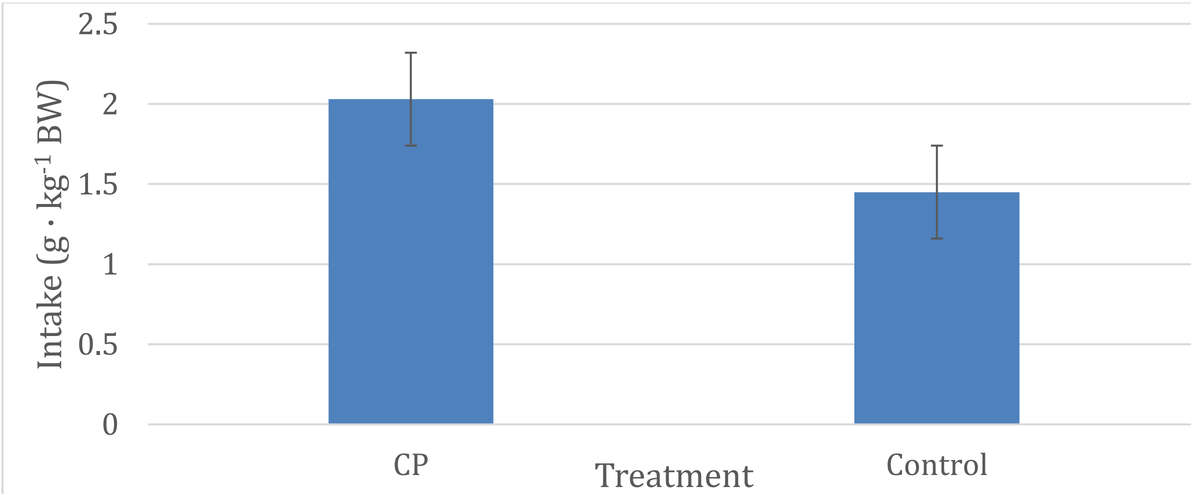

Figure 3. Average intake (g · kg^{-1} BW) of willow baccharis by goats fed additional protein vs the control (no supplementation) in Trial 2. Goats in both treatments were offered willow baccharis for 14 days.

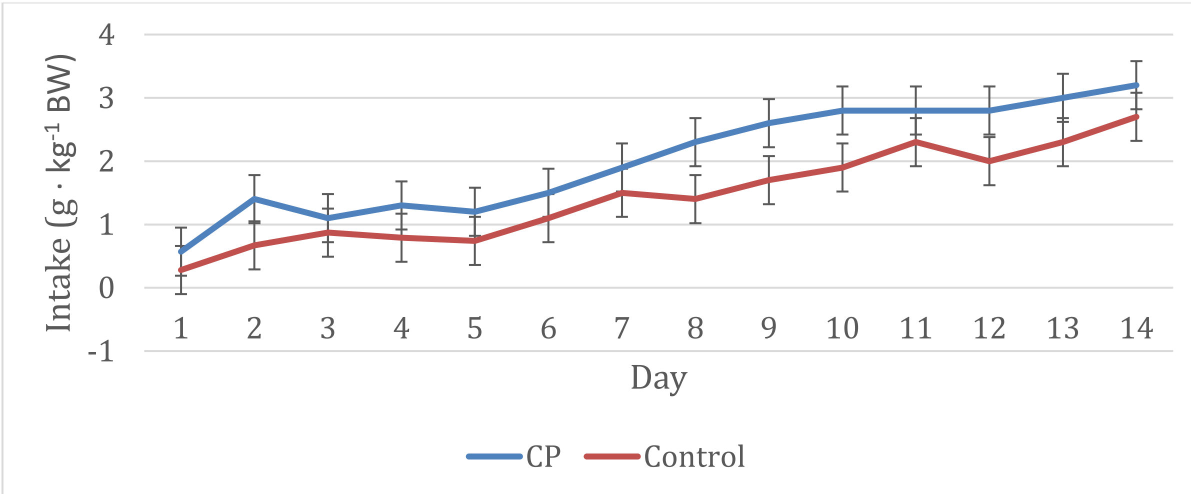

Figure 4. Average daily intake (g · kg^{-1} BW) of willow baccharis by goats fed additional protein vs the control (no supplementation) in Trial 2.

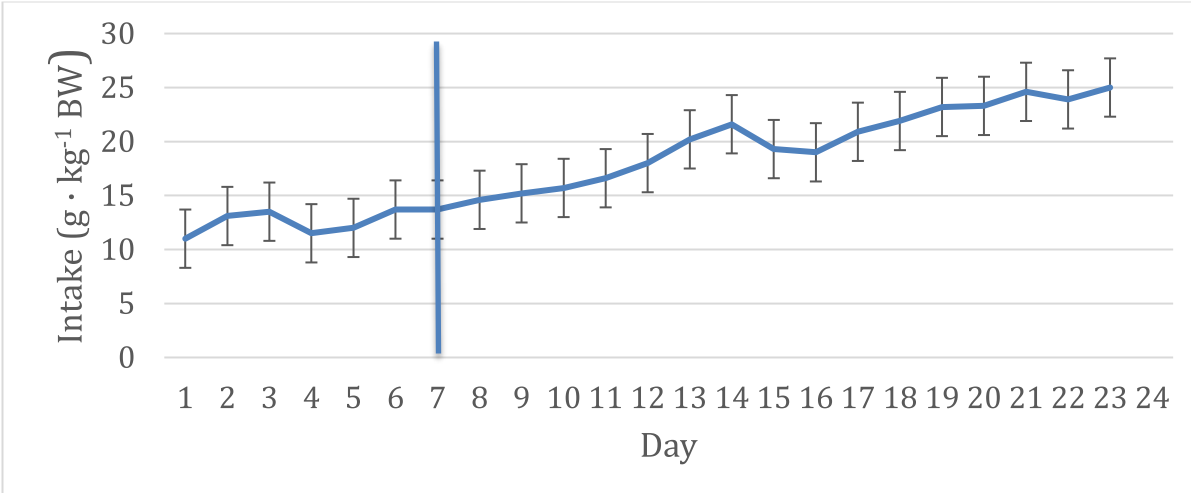

Figure 5. Average daily intake (g · kg^{-1} BW) of alfalfa by goats in Trial 2. Data are pooled across both treatments because the treatment by day interaction was similar (P > 0.05). For the first seven days, goats only received alfalfa pellets for pen acclimation.

DISCUSSION

Trial 1

Results from this study illustrate that goats dosed with activated charcoal ate more willow baccharis than goats not dosed (Fig. 1). Dosing with activated charcoal also improved intake of bitterweed (Poage et al. 2000). Both plants contain sesquiterpene lactones that cause aversive post-ingestive feedback and the formation of food aversions (Munoz et al. 2017; Fuchs et al. 2017.) Apparently, activated charcoal readily binds the toxins in both plants thereby attenuating aversive post-ingestive feedback. Others have noted that dosing with activated charcoal can alleviate the likelihood of some plant-induced toxicosis (Buck & Bratich 1986). Negatively charged toxins readily bind with activated charcoal and remain bound until excretion (Hayden & Comstock 1975). Conversely, activated charcoal appears to have little impact on some toxic plant intake. When goats were dosed with activated charcoal and fed juniper, dosing with activated charcoal appeared to have little impact on intake of the plant (Bisson et al. 2001).

Trial 2

Offering additional protein supplementation tended to increase intake of willow baccharis (Figs. 3 and 4). Although not significant, there was a trend for goats that were supplemented with protein to eat more willow baccharis. These goats tended to increase intake over time at a faster rate. The protein supplement used in this study contained cottonseed meal (CSM) and digestible dried grains (DDG) (Table 1). Both sources of protein contain amino acids that escape rumen degradation, resulting in absorption of amino acids in the small intestine. Some of these amino acids are glucogenic and can be used as substrates for toxin conjugation in the liver (Illius and Jessop 1995). This can result in toxin excretion through urination prior to toxicosis. Both cottonseed meal and DDG contain higher levels of the amino acids Alanine and Glutamine, both of which can affect gluconeogenesis and possible toxin excretion. George et al. (2010) showed that supplementation with the same supplement improved intake of the toxin-containing shrub redberry juniper. Similarly, Calhoun et al. (1989) illustrated that protein supplementation with supplements containing CSM improved intake of bitterweed, which contains similar toxins. Hymenoxon, the sesquiterpene lactone found in bitterweed, is partially metabolized and conjugated with glucogenic compounds in the liver followed by excretion in urine (Terry et al. 1983). Given the similarities in toxins between bitterweed and willow baccharis, feeding additional glucogenic amino acids should improve metabolism and excretion of the toxins found in willow baccharis. Although not significant, there was a trend for goats supplemented to consume more willow baccharis.

Potentially, activated could be combined with protein supplementation to further enhance toxin excretion and avoidance of toxicosis. Animals could be fed additional protein and dosed with activated charcoal prior to release on pasture. Others have fed activated charcoal mixed with a protein supplement (Bisson et al. 2001). Unfortunately, mixing with a supplement is difficult because of the fine particle size of activated charcoal. Most protein supplements are pelleted rations, where ingredients are exposed to heat and pressure to form a pellet. The pelleting process applied to activated charcoal changes the surface charge resulting in de-activation. Once deactivation occurs, charcoal will not bind with toxic compounds. In addition, there is some evidence that applying heat and pressure may result in some reactions that could lead to explosions during the pelleting process.

Exposure at weaning improves intake of some plants (Bisson et al. 2001; Dietz et al. 2010). Conversely, Munoz et al. (2017) suggested that exposure at weaning had little impact on willow baccharis consumption. In the current study, goats increased intake of willow baccharis throughout the 14 days of feeding, regardless of treatment (Fig. 4). It is unclear why goats increased intake in the current study but not in the data reported by Munoz et al. (2017). However, given that all goats lost weight during the study, it appears that goats were unable to meet their maintenance requirements by consuming alfalfa (3% BW) and willow baccharis. Goats may have consumed more willow baccharis even though they experienced some aversive post-ingestive feedback to attempt to meet maintenance requirements. Ruminants often consume poisonous plants while experiencing aversive post-ingestive feedback to meet nutritional needs (Provenza 1995).

IMPLICATIONS

Based on the results of this study and others, goats can be used as a biological control of willow baccharis if (1) goats are dosed daily with activated charcoal or (2) supplemented daily with a protein supplement similar to the one used in this study that contains sources of amino acids that escape rumen degradation and are glucogenic. For dosing with activated charcoal to be feasible, animals would need to be dosed prior to exposure to willow baccharis each day. Conversely, protein supplementation could be fed daily or provided free-choice to animals foraging on willow baccharis, without requiring daily penning and dosing. Future efforts should assess the effect of feeding additional protein and dosing with activated charcoal.

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APPENDIX

ANGELO STATE UNIVERSITY
College of Graduate Studies & Research
Institutional Animal Care & Use Committee

July 13, 2020

Cody Scott, Professor Agriculture
Angelo State University
ASU Station #10888
San Angelo, TX 76909

Your proposed project titled, "Increasing Acceptance of Willow Baccharis by Goats" was reviewed by Angelo State University's Institutional Animal Care and Use Committee (IACUC) in accordance with the regulations set forth in the Animal Welfare Act and P.L. 99-158.

This protocol was approved for three years, effective July 13, 2020 and it expires three years from this date; however, an annual review and progress report form (www.angelo.edu/content/files/22583-iacuc- annual-review-progressreport) for this project is due on August 15 of each year. If the study will continue beyond three years, you must submit a request for continuation before the current protocol expires.

The protocol number for your approved project is 2020-104. Please include this number in the subject line of in all future communications with the IACUC regarding the protocol.

Sincerely,

Chase Runyan

Chase Runyan, Ph.D.
Co-Chair, Institutional Animal Care and Use Committee